HOS 6.L

(Preliminary Draft)

BASIC INTERPRETATION OF PHOTOS

PACIFIC NORTHWEST REGION

Adapted From

"Aerial Photographs in Forest Inventory and Forest Management" (unpublished)

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BASIC INTERPRETATION OF PHOTOS

Introduction

The Basic Interpretation of Photos course is an aerial photo interpretation course designed to be used at the Forest or District level in Region 6, U. S. Forest Service. It contains introductory material on the characteristics of aerial photography. There are directions for aiding the student to see stereoscopically. Instructions are given for determining photo scale and measuring horizontal distances, angles, and areas on aerial photos. Some general principles for identifying natural and cultural features on aerial photos are included. The course does not give instruction for measuring vertical distances (tree heights, etc.). Height measurement on photos requires a specialized course of instruction and a great deal of practice to attain proficiency. It is not generally used at the District level.

Trainee instruction materials include a manual; a group of stereograms, aerial photos and photo aids (the BIP Kit); a group of slides; and a number of photo interpretation tools. The manual and BIP Kit are obtained from the Division of Engineering in the Regional Office. The slides are loaned on request. The photo interpretation tools should be furnished locally.

The instructor is furnished a course outline and an answer sheet for the problems in the manual.

Instruction Material

The "BIP Kit"

PIA #4 - Stereograms 1, 3, 5, and 8
TSA #6 - Area Grid
TSA #16 - Multiple Scale
EGI 1-153 and 154 - Aerial Photos
EGI Map - Planimetric, 1:31,680
ELC 2-156 - Aerial Photo (Lithograph)
ELC Map - Planimetric, 1:15,840
ELC Map - Topographic, 1:62,500
ESG 6-26 - Aerial Photo (Lithograph)
ESG Map - Topographic, 1:24,000
Floating-Circles Test

Photo Interpretation Tools

Pocket Stereoscope
Engineer's Scale
Grease Pencil
Slide Rule (optional)

CHAPTER 1

CHARACTERISTICS OF AERIAL PHOTOGRAPHS

This chapter describes the kinds of aerial photographs commonly available, tells how they are taken, and gives some pointers on their relative usefulness in forestry work. Its aim is to provide sufficient background information so that a forester can use aerial photos intelligently as a working tool.

Types of Photography

Vertical Photography

Vertical aerial photographs, taken with the camera pointing straight down, are useful for both mapping and interpretation. They are not precise maps. However, they are good enough to serve as map substitutes for many forestry purposes, and accurate maps can be made from them with suitable plotting instruments and sufficient ground control. Vertical photos are usually taken so that they overlap each other, permitting them to be viewed stereoscopically. This gives a three-dimensional image that reveals far more detail than can be shown on a map.

Because it is the most widely used type of photography, the term "aerial photograph" has come to imply "vertical," and will be so used in this manual.

Oblique Photography

Oblique photos are taken with the camera tilted at an angle between vertical and horizontal. Although they cover more area than a vertical taken from the same height, they are seldom used for forestry purposes in this country. The photo scale changes continuously from foreground to background, making it difficult to use them stereoscopically or to make measurements. Obliques are sometimes used in special plotting instruments to make maps, and they are excellent for general illustration.

Films and Filters

Black and White

By far the bulk of the aerial photography used for mapping and forest interpretation in the West is taken on panchromatic film. A medium yellow (minus-blue) filter is generally used to minimize the effects of haze.

Panchromatic film has about the same sensitivity to the visible spectrum as does the human eye. Hence, it reproduces various colors in shades of gray that look "normal." Although it is sometimes handicapped by lack

of a pronounced tone contrast between conifers and hardwoods, panchromatic film is probably the most universally acceptable film for general forestry purposes. Other films or filters may be better for specific uses, and are sometimes justified for special projects.

In the eastern half of the country, infrared film is often used because it shows a greater tone difference between conifers and hardwoods. It may be exposed through a red filter for maximum contrast, or through a minus-blue filter for a "modified infrared" effect. This film is seldom used for photographing western forest lands where conifers predominate and the separation of hardwoods from softwoods is usually not an important consideration.

Color

There are several kinds of aerial color film of interest to foresters. One produces positive color transparencies. Another yields a reversed color negative from which both black-and-white and color prints can be made. Kodak Ektachrome Infrared film, a combination of color and infrared emulsions gives a false color transparency, useful in insect and disease detection. Color films have proved to be worth their extra cost for certain special purposes, such as the evaluation of insect damage, and it is possible that they may be used more in the future for detailed management purposes.

Season and Time of Photography

In order to keep shadows to a minimum, most photo contracts restrict flying to the summer season and the middle portion of the day. Although sometimes used in other parts of the country, winter photography is seldom attempted in the Pacific Northwest. In addition to the excessive shadows caused by tall timber and steep topography, winter flying days are scarce, snow often obscures much of the ground detail, and leafless hardwoods are difficult to detect.

Some photo projects in this area have been taken as late as September or October. These generally have objectionable shadows and should be avoided if possible.

Photographic Prints

Contact Prints

Most photo interpretation is done on prints the same size as the negative, called contact prints. These may be obtained on single-weight paper, which is suitable for office use and the construction of mosaics, on double-weight paper for normal field use, or on cronopaque or waterproof paper for field use in wet weather.

Aerial photo prints are most commonly furnished in a dull, slightly roughened surface known as semimatte. This is best for field use because it reduces unwanted reflections and is easy to write on.

A glossy surface is sometimes used for office interpretation. It contains more fine detail than semimatte, but cracks when bent, is difficult to write on, and sometimes creates annoying reflections. Air-dried glossy, a compromise between glossy and semimatte, can also be obtained.

Enlargements

Enlargements are seldom used in forest photo interpretation, because they are difficult to use steroscopically, and generally contain no more detail than contact prints. They are sometimes useful in field mapping because they provide more room for writing symbols. They are particularly helpful when making a detailed survey or planning the development of a small area, such as a campground.

Mosaics

A mosaic is a composite picture made from the central portions of overlapping aerial photos. The prints are trimmed and assembled so that photo detail matches, giving the appearance of a single, large picture. If the photos are simply positioned by eye so that details match as closely as possible, the mosaic is called uncontrolled.

A controlled mosaic is produced from rectified prints. Rectification uses ground control to bring 3-6 points per photo into scale adjustment. This serves to minimize the effects of tilt and topographic displacement. The prints are also tone matched so the joints between photos would not be so obvious.

An even more accurate photo-map can be obtained with orthophotography. An orthophoto is a photo that has been incrementally rectified in a series of small areas about the size of a postage stamp or less. This rectification virtually eliminates the effects of tilt and topographic displacement from all parts of the photo. The result is a photograph which is nearly the equivalent of a planimetric map. The process is expensive, therefore, the procedure is usually applied to small scale photos which are then enlarged to the desired scale.

The photo index is a crude mosaic made as a handy reference for locating and orienting photos rather than as a map. Entire prints are laid down, overlapping each other, with detail approximately matched and the photo numbers showing. Then the assembly is photographed at a reduced scale and used as an index to photo location.

How the Photos are Flown

Vertical aerial photos are normally flown in a series of parallel flight lines oriented in cardinal directions. Camera exposures are so timed that adjacent photos along the flight line overlap by an average of about 60 percent (endlap). This insures that every point on the ground shows on at least two photos, making steroscopic viewing possible. Flight lines are generally spaced so that adjacent photo strips overlap an average of 30 percent (sidelap).

Figure 1 shows how photos should look when correctly flown, and also illustrates crab and drift, common deficiencies that can cause insufficient sidelap. A photo defect that is much more difficult to spot is tip or tilt. Generally it becomes known only when photos are placed in plotting instruments and measurements compared with ground

control. Amounts of tip and tilt generally present in photos do not seriously affect the kind of distance and angle measurements made by foresters. However, they do sometimes contribute to the error of measuring tree heights or elevation differences.

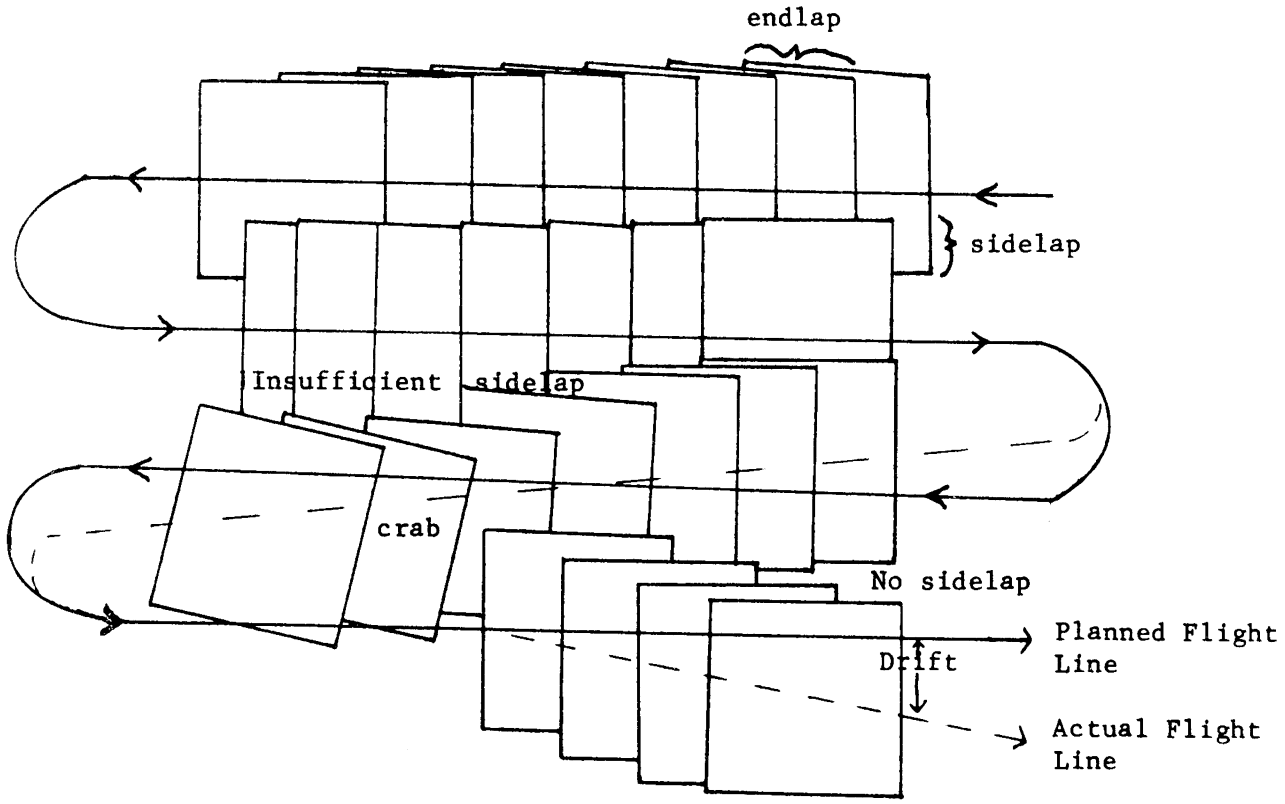


Figure 1.--Diagrammatic Flight Map

Scale and Focal Length

American foresters generally express photo scale the same way they do map scale--by a representative fraction or ratio. This ratio expresses the relative size of distances on the photo and on the ground. That is, a scale of 1:15,840 means that one unit of measure on the photo equals 15,840 like units on the ground. Engineers usually speak of scale in terms of feet to the inch, and Canadian foresters tend to use chains to the inch. Equivalents for the scales most commonly used in forestry are shown below.

Scale Ratio	Feet to the inch	Chains to the inch	Inches to the mile
1:12,000	1,000	15.15	5.28
1:15,840	1,320	20.00	4.00
1:20,000	1,667	25.25	3.17

The scale of a photograph depends on the height of the plane above the ground and on the focal length of the camera lens. The closer the plane is to the ground, or the longer the focal length, the larger the photo scale; that is, the larger the image of a particular ground feature.

Since the distance between the aircraft and the ground is different for nearly every spot of ground, the scale changes from place to place on the photo. Ridgetops are pictured at a larger scale than valley bottoms. Moreover, the average scale of one photo is likely to be different from that of other photos. As a result of this, a photo project which is supposed to be 1:12,000 may have individual average photo scales ranging from 1:10,000 to 1:15,000, and the average scale of all prints in the project might turn out to be 1:12,500 rather than 1:12,000. Methods of determining photo scale are presented in chapter 3.

With a lens of short focal length, a given photo scale is obtained at a lower flying height than that required for a longer lens. Short-lens photography produces a greater depth in the stereoscopic image, and more displacement due to topographic relief. This is often desirable for making contour maps, but such photography sometimes makes it difficult for interpreters to fuse images of tall trees.

Mapping photography at scales of 1:20,000 and smaller is usually taken with a short (6-inch) lens. Most 1:20,000 scale photography for forest or agricultural interpretation is taken with a medium (8 1/4-inch) lens. This lens is also used for 1:15,840 scale, producing satisfactory photos in most cases. Scales as large as 1:12,000 are sometimes taken with an 8 1/4-inch lens, but this often makes it difficult to fuse the tops of tall trees. A 12-inch lens is preferred for this scale in the tall timber of the west coast.

Information Appearing on the Photographs

The information appearing on Forest Service photographs follows a standard format. The project symbol, roll number, and exposure number appear in the upper right corner of each photo. This roll number should not be confused with the flight-line numbers that appear on the photo indexes. The same roll number may appear in several flight lines. On the other hand, there can be a change of roll number in the middle of a flight line.

The date of photography appears in the upper left corner of each photo. The end photos in the flight line indicate the time of day, the contracting agency (FS), the nominal project scale, and the focal length. This information also appears when roll numbers change.

Fiducial marks, usually shaped like half an arrowhead, appear midway along each border of aerial photos. Their purpose is to locate the principal point (center of the photo) by intersecting lines connecting opposite fiducial marks.

CHAPTER 2

THE THREE-DIMENSIONAL IMAGE

The detailed picture of the ground surface contained in a vertical aerial photograph forms a highly useful, though not necessarily precise, map. Many objects are easily identified from their images on single photos, and there is often an illusion of topographic relief, making it possible to distinguish some of the most prominent land forms. This information is sufficient to enable an experienced interpreter to learn much about the country pictured and to do a pretty fair job of finding his way around in the field.

However, even the experienced interpreter will miss much if he works only with the flat two-dimensional image of single photos containing limited illusions of relief. The true shape of objects and of the ground surface can be seen only in the three-dimensional image created by viewing a properly oriented pair of overlapping photos.

Looking at such an image gives the viewer a feeling that he is suspended in air over a model of the terrain. Ridges rise above valleys, trees and buildings stand up from the ground, relative heights and the steepness of slopes can be judged, and objects become easier to identify. He can do a better job of judging the ground conditions and can find his way around in the woods more efficiently, with less risk of getting lost. Moreover, the vertical dimensions of this image can be measured, making it possible to estimate tree heights, elevation differences, and slope percents.

In order to take advantage of this ability of aerial photos to produce an image with depth, it is necessary to know a little bit about how it works, how to orient the photos for proper viewing, and how to use a stereoscope. Such is the purpose of this chapter.

How It Works

When we look at a scene, it has depth; we can judge which objects are near to us and which are far. A number of things contribute to this judgment, but one of the most important is the fact that each eye has a slightly different viewpoint, and therefore receives a slightly different image. The fusion of these two images in the brain creates a single three-dimensional image.

When vertical aerial photos are taken with the standard 60-percent overlap, each object on the ground will appear in at least two of the photos. The image of a particular object will be somewhat different on adjacent photos because each was taken from a different viewpoint. When two such photos are properly oriented and viewed, each eye sees only one picture. The two slightly different images are fused in the brain into a single three-dimensional model, in which objects exhibit shapes, slopes, and heights similar to those in the real scene.

The manner in which this takes place is not completely understood, for the process is psychological as well as optical.

When you study the stereoscopic image created by an overlapping pair of aerial photos, you will get an impression of how steep the slopes are. When you get out on the ground in this area and start to climb some of these slopes, you will probably find that they are either steeper, or perhaps not as steep, as you thought they were. The impression of steepness that one gets from the stereoscopic image will vary from person to person because it is partly psychological and it depends somewhat on that person's experience. Thus, the amount of vertical "exaggeration" or "flattening" in the stereoscopic image from a particular pair of photos cannot be predicted exactly. However, most people feel that photos taken with a 12-inch lens tend to "flatten" the terrain, while those taken with an 8 1/4-inch lens tend to exaggerate the steepness of slopes. You will have to learn for yourself, by experience, how to interpret the appearance of steepness from the kind of photos you are using.

Stereoscopes

A stereoscope is the optical device that makes it easy for each eye to see only one of the photos. If we look at the photos without a stereoscope, our eyes tend to focus for this short distance and the visual axes converge on the point we are studying. In order to make each eye see a different photo we have to separate the visual axes so that we are no longer looking at a single point but at two different points.

The stereoscope facilitates this. Lens stereoscopes separate the visual axes by causing our eyes to focus at infinity, as when viewing a distant scene. The visual axes then tend to become parallel and we can look at two different photos separated by the approximate distance between our eyes. Lens stereoscopes are inexpensive and easy to carry around, often folding to pocket size. They usually magnify two to four times, but this restricts the vision to an area about two inches in diameter.

Reflecting stereoscopes separate the visual axes by means of prisms and mirrors. The simple mirror stereoscope, with its wide photo separation and broad field of view, permits one to see the entire overlap area of a photo pair, but provides no magnification. Binoculars mounted on some models magnify the image but restrict the field of view. Reflecting stereoscopes are generally quite expensive and not portable enough for field use.

It is possible to view a pair of photos stereoscopically without using a stereoscope, and many experienced interpreters have developed this knack of "naked stereo." The problem is to get your visual axes parallel, as in distance viewing, at the same time focusing at reading distance. How- is a useful trick for occasions when no stereoscope is available. However, the unnatural muscular action is tiring and there is some evidence that too much of this might lead to eye trouble.

Orienting the Photos

After a little practice you will be able quickly to get a pair of photos in approximate orientation good enough for quick study, as in the field. However, in order to make height measurements and to minimize eye strain on lengthy interpretation jobs, the photos should be carefully oriented. This involves getting the photos properly aligned and separated by a distance which is suitable to your eyes. The following steps will result in correct photo orientation for use with a lens stereoscope:

1. If you do not already know it, you will first need to determine the photo separation best for your eyes. You can begin by measuring the distance between your eyes, using a mirror or having someone do it for you. Then set the lenses of your stereoscope at this spacing.

Now, set the stereoscope on plain paper, close one eye, and draw a cross in the center of the field seen by the open eye. Open both eyes, put your pencil under the other lens, and mark another cross where it appears to be right on top of the first one. The distance between the two crosses will be an indication of the proper photo spacing. It usually runs from 2.0 to 2.5 inches and will be less than your eye base by a few tenths of an inch, though with some people it may be as much as an inch less. You will find that as you gain experience you will be able to tolerate a range of spacings and will be able to see stereo on photo pairs set up by someone else, even though the spacing is different from yours.

Many stereoscopes have a millimeter scale on their lens separation bar so that once a satisfactory lens separation is determined, it can be set before the stereoscope is put into use.

If glasses other than reading glasses are normally worn by the photo interpreter, they should also be worn when looking through a stereoscope.

2. Take two photos which are adjacent along the flight line and trim the excess borders, being careful not to remove the fiducial marks. Locate the center, or principal point, of each photo with a Photo Alignment Guide. Such a guide enables you to locate the photo center in one step by lining up all four fiducial marks at once. It is also useful in step 4 to orient the photos and get them the right distance apart. If you do not have a guide, you can use a straightedge to make intersecting lines between pairs of opposite fiducial marks. Mark the location of each principal point, preferably with a needle prick and a visible circle.

3. Since the photos overlap by more than 50 percent, the image of the principal point of each photo shows up on the companion photo, an inch or so from the edge, where it is called the conjugate principal point. You can determine the precise location of these by carefully comparing image detail on the two photos. However, it can be done more quickly by viewing the two photos stereoscopically, if you have already acquired this knack. If you have not, continue reading this chapter and work the problems at the end. After you have learned to see stereo on the prepared stereograms, you will be able to use this method for

locating conjugate principal points. When transferring points stereoscopically, place the needle point in position and then double check by blinking each eye alternately. This will quickly show you whether or not the needle point is really at the same location as the pricked hole on the other photo. Having located the conjugate principal points, one on each photo, mark them the same as you did the principal points.

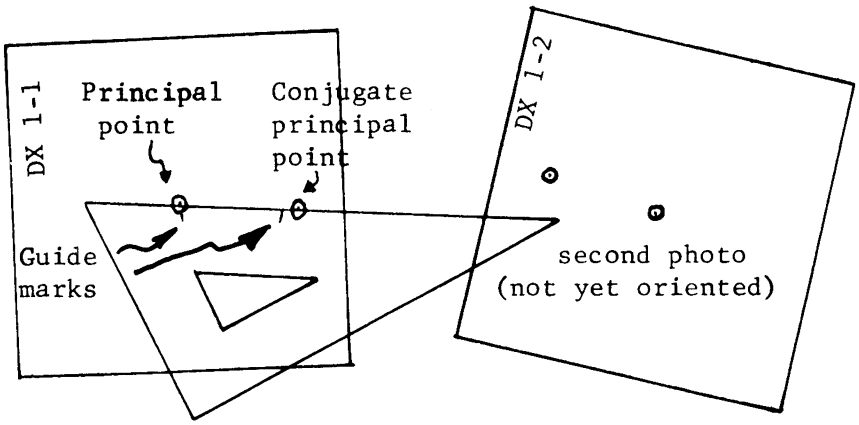
4. Now you have marked four points, two on each photo. The next step is to orient the photos with all four points in line and the photos separated by your stereo spacing as determined in the first step. If you have purchased or made some sort of photo alignment guide, use it to orient the photos. If not, you had better pause at this point and make a simple guide from a strip of heavy plastic or a drawing triangle. Simply make two marks along the edge, one about four inches from the end, and the other separated from it by your stereo distance. Such a guide is shown in figure 2, page 11.

Figure 2 demonstrates the procedure for proper orientation. To begin with, place the photos with the flight line running from side to side and the areas of common overlap adjacent. If you are a beginner, it may help to have the shadows falling toward you rather than away from you. Shadows falling away from the interpreter (toward the top of the photos) may create an illusion of reverse depth which is sometimes a psychological hazard to the beginner. After you have gained experience, you will want to ignore this recommendation and orient the photos north if you are using a map, or in the same direction as the ground if you are in the field.

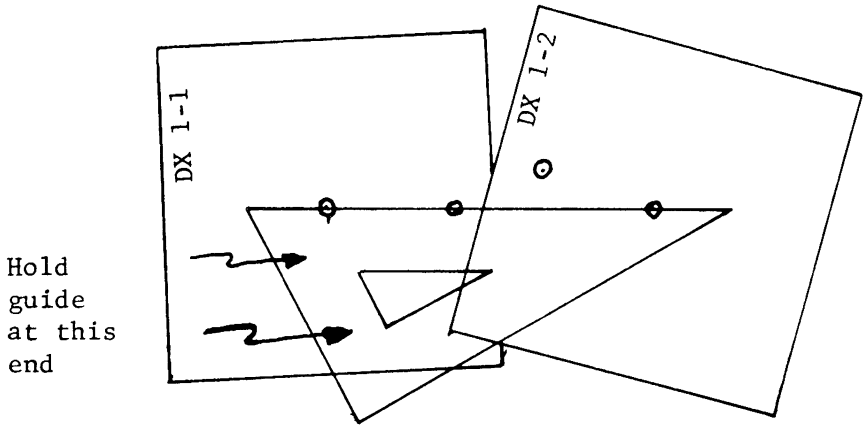
Place your alignment guide on one of the photos with one of the spacing marks on the principal point and the straightedge passing through the conjugate principal point, as shown in figure 2a. Now hold the guide firmly at the end so it will not slip, and slide the second photo between the guide and the first photo, as in figure 2b. Still keeping the guide from moving on the first photo, adjust the position of the second photo so that the conjugate principal point is on the second spacing mark and the straightedge goes through the principal point, as in figure 2c.

5. Now fasten the photos down so they cannot change position. The best procedure is to fasten the outside edge of each photo to the desk with drafting tape or to a steel plate with magnets. Or you can make a photo holder from clipboard clamps. These methods permit you to flip either photo on top of the other without disturbing their alignment. If you do not foresee a need to reverse the position of the photos, you can simply tape them together or use paper clips.

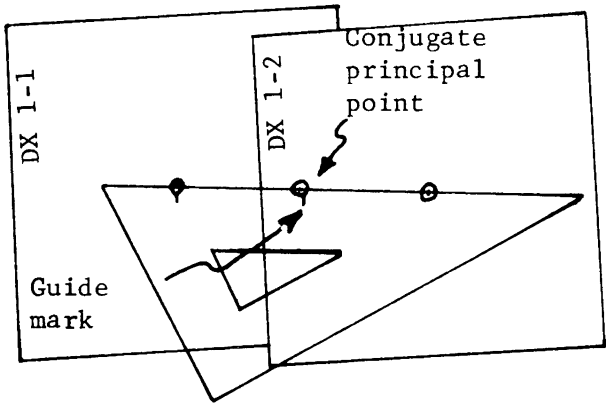
The method of aligning photos for viewing with a mirror stereoscope is similar, except that the spacing between photos will be much greater--usually around nine inches.



2a Guide oriented on first photo



2b Sliding second photo into position



2c Final orientation complete

Figure 2.--Orienting the Photos for Proper Stereoscopic Viewing

Viewing the Photos

Now that the photos are properly oriented, place your stereoscope on the photos with the lenses parallel to the flight line and each lens over one of the images of the area you wish to view. Look through the stereoscope, rotate it back and forth slightly to make sure it is properly aligned, and the two images should fuse together into a three-dimensional model. If they do not, pick out a prominent object and look at it first with one eye then the other, by blinking alternate eyes rapidly. The object will probably appear to shift position slightly as you do this. Experiment by rotating the stereoscope or changing the lens spacing until you get rid of this shift. Then open both eyes and you should be seeing stereo.

When viewing a stereopair of aerial photos with the standard lens stereoscope, the field of best vision is limited to an area about two inches in diameter. It is possible to see a much larger area by looking obliquely, but it is better to move the stereoscope so it is directly over the area of interest. Whenever you first look through the stereoscope in a new position, it is desirable to rotate it back and forth slightly to get it in the best possible alignment. This will occur when the stereoscopic image is clearest and most comfortable to view.

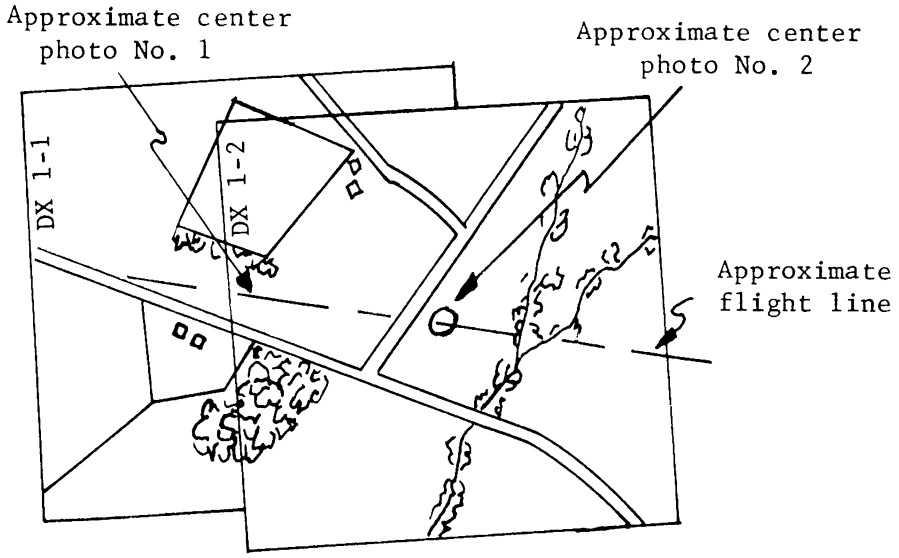
Proper illumination is also important for comfortable viewing. An adjustable fluorescent desk lamp works best. It can be brought close to the photos so you are not working in the shadow of your own head. The long light source also helps eliminate shadows from parallax instruments or other photo aids.

With photos oriented as they are in figure 2c with the right-hand one on top, you will be able to see stereo only along the left side of the overlap area. By flipping the photos so the left one is on top, you can view the right side of the overlap. However, there will be a portion in the center of the overlap that can be seen only by curling up the edge of the upper photo. This procedure is alright for viewing, but the photos have to be flat for height measurements with parallax instruments. The simplest way to beat this is to cut a strip off the edge of the photo. There is nothing sacred about a photo edge, once the principal point has been located; just be sure you do not cut so deep you lose stereo on part of the overlap.

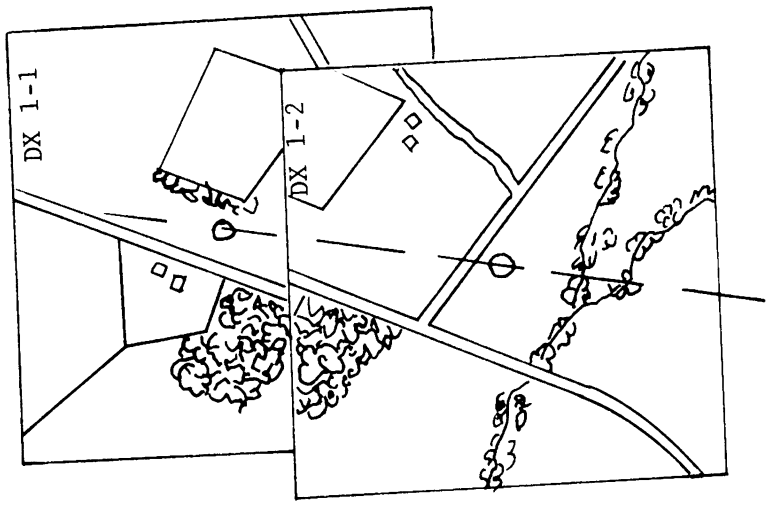
Approximate Orientation Procedure

The orientation procedure described is desirable for extensive study or when estimating heights by parallax measurements. However, for casual inspection in the office or when using the photos in the field, you can arrive at a satisfactory approximate orientation without having to mark the principal and conjugate principal points. Figure 3 illustrates how this is done. First place one photo on top of the other so that the image detail matches, as if it were a mosaic. Pick a point at the approximate center of the top photo, and also estimate where the center of the bottom

photo would be. Establish an imaginary line through these two points. This is the estimated flight line. Now simply pull the two photos about 2 1/4-inches apart along this imaginary flight line, without changing their angular orientation.



Photos oriented with detail matched



Photos pulled apart along approximate flight line

Figure 3.--Method for Approximate Photo Orientation

Place the stereoscope on the photos, parallel to the approximate flight line, and make the final orientation adjustments. Use the previously described method of picking out a prominent object and rapidly blinking alternate eyes. Observe which way the image shifts as you do this and adjust photos and stereoscope to remove this shift. At the same time, check the angular orientation of the photos by noting if the image rotates back and forth slightly as you blink alternate eyes. If it does, rotate one photo a little to correct this.

It is a good idea to practice this method of approximate photo orientation until you become proficient. If you have difficulties in a comfortable, well-lighted office, you will be in real trouble in the dim light of the deep woods under a dark sky, squatting on your haunches with rain dripping down your neck and mosquitoes attacking. Some pointers on using the photos in the field are contained in chapter 5.

Depth Perception

While most people have little difficulty seeing stereo once everything is properly oriented, some have visual defects that prevent normal stereoscopic perception. And among people who can see stereo, there are differences in ability to detect small differences in depth. Some beginners do not seem to be sure whether or not they are really seeing the image stereoscopically. Problems one and two have been designed to help you determine if you are really seeing stereo or just imagining it. You should also try the floating-circles test for stereoscopic perception.

CHAPTER 3

BASIC PHOTO MEASUREMENTS

This chapter covers the basic photo measurements of scale, distance, angle, and area. These, along with height and elevation difference, are the measurements that enable you to get useful quantitative information from the photos, whether you are cruising, running landlines, laying out roads, or working on timber sales.

Making these measurements on maps is a straightforward process, for on a well-made map every object is shown in its correct position. A truly vertical aerial photo of level land can be treated as a map. However, these conditions are rare, and both irregular terrain and tilted camera axis cause object images to be displaced from their true position.

This is not a serious stumbling block for the relatively crude measurements that usually meet forestry needs. However, it is well to be aware of these error sources so you can make your measurements in a way to minimize them. We will first look at the reasons for these image displacements, then see how we can reduce their effect when making the various measurements. In the examples used to illustrate the various methods, we recommend you make the measurements yourself and follow through step by step so you understand the method clearly.

Image Displacements

Displacement due to topographic relief is the main reason why many objects in a photo are not at their true map position. This results from the perspective view characteristic of all photographs. The aerial camera looks straight down on objects only at the photo center. Every other point is seen from an oblique angle. This is evident in the photo corners where tall objects such as trees appear to lean out from the photo center. The same displacement is caused by changes in the ground elevation, but the effect is not so apparent.

The leaning trees demonstrate one of the principles of relief displacement in a vertical aerial photo: that objects at different elevations are displaced from their true positions along lines which radiate from the photo center. If we establish an arbitrary elevation for reference, called the datum, objects at this elevation will be in their true position at datum scale. Objects above datum will be displaced outward, away from the photo center, while objects below datum will be shifted in toward the photo center.

Figure 4 shows the geometry of this displacement. If we were making a map at the scale of the datum elevation, the hilltop should appear at point (b). However, because of its elevation, it has been shifted out from the photo center and shows up on the photo at point (a). Similarly, the river has been shifted toward the photo center because it is below the datum.

There are several characteristics of topographic displacement you should keep in mind when making photo measurements. The displacement occurs along lines which radiate from the photo center (this is not strictly true for tilted photos, but is satisfactory for most practical purposes). Thus, angles measured about the photo center will not be affected by relief displacement, but angles measured elsewhere on the photo may be erroneous. Therefore, in measuring angles, choose the photo with center nearest the angle vertex.

Topographic displacement is inversely proportional to flying height above the datum. Thus, you should be especially alert to measurement problems if you are working with photos of a large scale or taken with a lens of short focal length, since these normally indicate low flying heights.

Displacement is directly proportional to the distance of the image from the photo center. There is none at the center, and it reaches a maximum at the photo edge. For this reason the central portion of the photo is often the only part used for type mapping or when laying mosaics.

Topographic displacement is also directly proportional to the elevation of the object above or below the datum plane. This is what makes it possible for us to measure tree heights and elevation differences on aerial photos, but it means that, the rougher the country, the more careful we should be with our distance and direction measurements.

The other source of image displacement affecting photo measurements is camera tip or tilt, which occurs in varying amounts despite the photographer's efforts to prevent it. The amount of tilt normally present in aerial photos seldom seriously affects the ordinary distance, angle or area measurements made by foresters. This is fortunate, for tilt cannot be assessed or corrected with the information and instruments generally available. You can sometimes choose your measurement points to minimize errors from this source. But beyond this, you will be obliged to ignore the problem, and you can be reasonably confident that your horizontal measurements are not seriously affected.

Tip and tilt can be a serious problem in measuring heights or elevation differences, a fact which has only recently been fully appreciated.

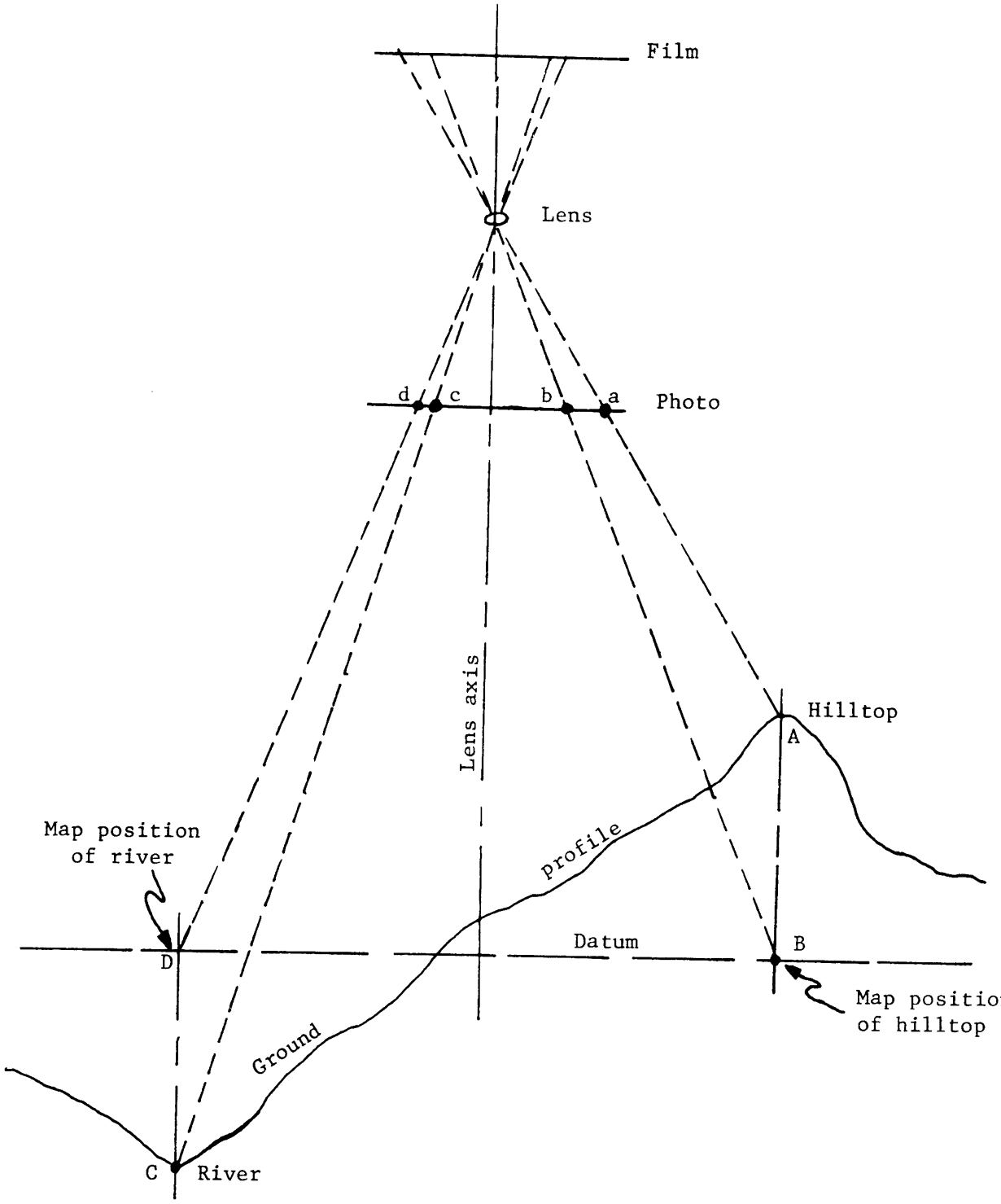


Figure 4.--Geometry of displacement due to topographic relief.

Measuring Photo Scale and Horizontal Distance

Aerial photo scale determination and distance measurement are inseparably tied together. Photo scale must be known before photo measurements of distance or height can be converted into corresponding ground figures. Yet, the most common method of determining photo scale is to compare distances measured on the photo with corresponding distances measured on maps or on the ground. In the following discussion, scale determination and distance measurement are covered under separate headings. However, because of their interdependence, they should be studied together.

Basic Theory

The geometry of photo scale and distance measurement is shown in figure 5. Following are the definitions for the symbols used:

- f = Focal length of camera, or distance from optical center of lens to film.
- H = Flying height above sea level.
- h = Elevation of ground above sea level.
- $H-h$ = Flying height above ground.
- GD = Ground distance.
- PD = Photo distance.

The relationship of similar triangles in this diagram gives us two ways of getting photo scale: one based on the ratio between focal length and flying height, the other based on the ratio between photo and ground distances. In the formulas that follow, we have turned the representative fraction upside down so that we deal with the photo scale reciprocal (PSR). The fraction itself is awkward to handle in formulas, and it is the denominator we are really after. In using these formulas, it is necessary to express all values in the same unit of measurement, such as chains, feet, or inches. Since flying height is expressed in feet, focal length must be too. An 8 1/4-inch lens is .6875 feet, a figure you might as well commit to memory.

If flying height and focal length are known, photo scale can be determined by:

$$PSR = \frac{H-h}{f} \qquad (1)$$

Since (H-h) is different for each ground elevation, the calculated scale applies only to points at that elevation.

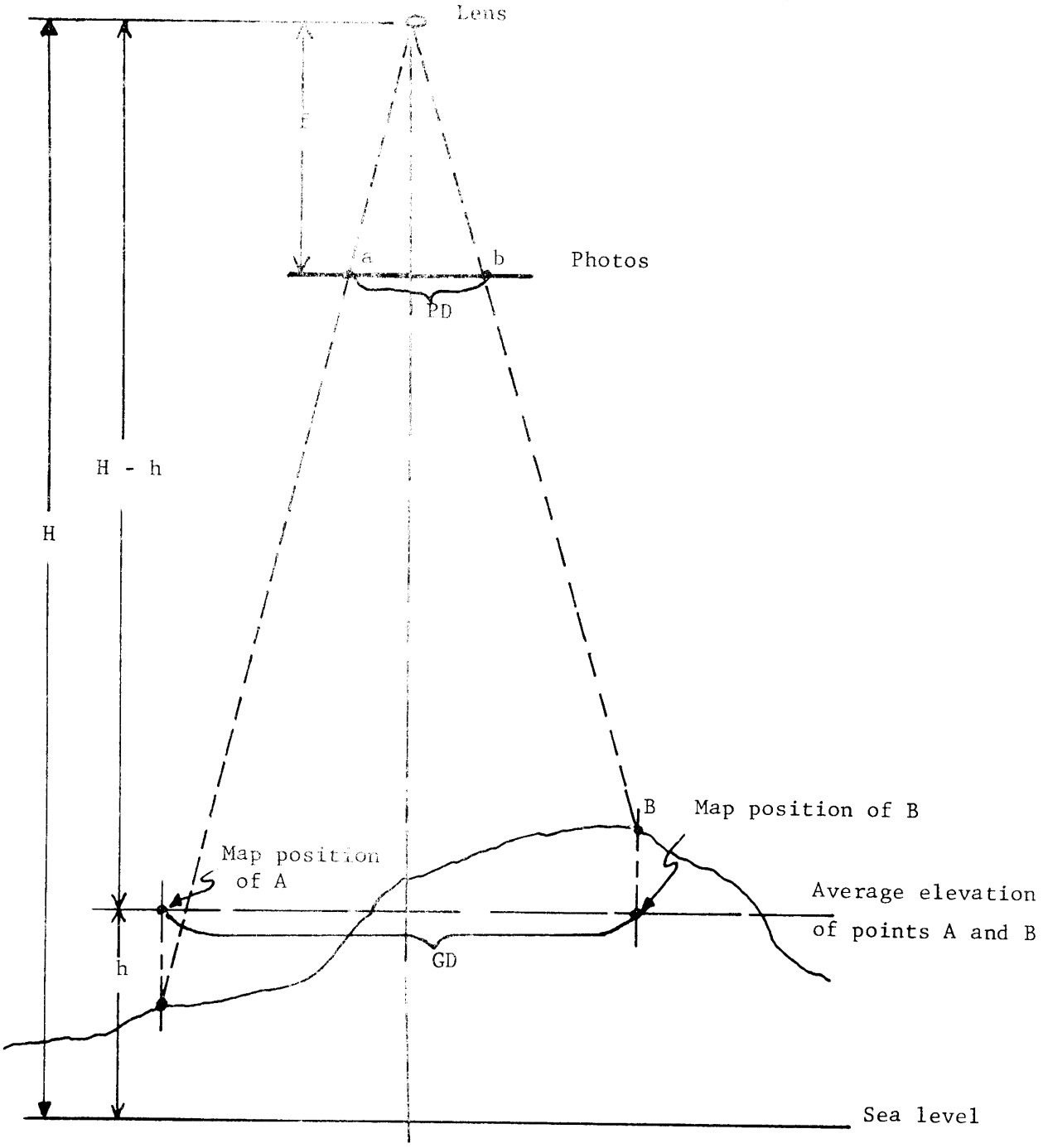


Figure 5.--Geometry of photo scale and distance measurement.

Example 1.--Given: flying height above sea level, (H) = 14,000 feet; average elevation of terrain in photo, (h) = 800 feet; focal length of camera, (f) = 8 1/4-inches or .6875 feet. Find: photo scale at average elevation (800 feet). Using formula 1:

$$PSR = \frac{H-h}{f} = \frac{14,000 - 800}{.6875} = \frac{13,200}{.6875}$$

PSR = 19,200 at an elevation of 800 feet.

This formula is not used very often, because actual flying height is often not known. You may occasionally find flying height noted on the photo margin, but it is seldom reliable enough to be useful. The main value in this formula is that, once we have found the scale for a particular ground elevation, it gives us a basis for getting the scale at any other elevation.

Most photo scales are calculated by determining a ground distance and measuring the corresponding distance on the photo. The formula is:

$$PSR = \frac{GD}{PD} \qquad (2)$$

Again, the calculated scale applies to a particular elevation, the average elevation of the two points at the ends of the measured line.

Example 2.--In stereogram 1, suppose we select for a scale checkline the road between point 4 and the road junction to the south. The topographic map tells us that point 4 is at an elevation of 960 feet and the junction to the south is 1,000 feet. Average elevation of the two points is (960 + 1,000)/2 = 980 feet. We measure the distance between the two road junctions on the ground as 12.5 chains. On the stereogram, the distance measures 0.74 inches. What is the photo scale at this elevation? Using formula 2:

$$PSR = \frac{GD}{PD} = \frac{12.5 \text{ ch.}}{0.74 \text{ in.}} = \frac{9,990 \text{ in.}}{0.74 \text{ in.}} = 13,500$$

at 980 feet elevation.

Practical Scale Determination

There are several ways of getting both the ground and photo distances needed to compute photo scale. Which is best? This depends on several circumstances, and no method is consistently best. Each time you calculate photo scale, you will have to examine the situation and pick the method which seems best. In the following discussion we will try to provide you with a basis for selecting the quickest and easiest method that will give reliable results.

Determining Ground Distance.--The quickest and easiest way to get ground distance is to take advantage of the rectangular landlines that appear on some photos. In developed areas these show up as regular intervals between parallel lines formed by roads, fences, or clearcut boundaries, as in stereogram 1. These lines will be 1/4, 1/2, or 1 mile apart, and with a knowledge of the approximate photo scale, or a map, you can easily tell which. If only one pair of parallel lines is visible, better not use it unless you have a map indicating that the sections are regular. Without it, you risk getting the wrong scale because of irregular sections. However, if you find several pairs of lines all measuring about the same distance on the photos, this is just as good as having a ground-measured distance.

If your photo does not show landlines, the next easiest way of getting a ground distance is from a map. Of course, it must be a reliable map, and you must be able to identify at least two suitable checkpoints, on both map and photo. If you want maximum precision, try to pick two pairs of checkpoints, more or less balanced across the photo center, as in figure 6.

If you cannot find at least two good points for a scale checkline, there are two tricks that may solve the problem, at least if you are doing this in the office. You may be able to join several photos, with detail matching, until you can reach between two identifiable points. Or, if small scale photos are available, you can determine their scale from the map, and then use them to get the scale of your photo.

The third way to get ground distance is to chain between two points you can spot on the photo. It is best to have at least a 10-chain stretch and, if possible, to locate it at the same elevation where you intend to make your photo measurements. Along roads or across openings is best, for chaining through steep or brushy country is a tough way to get photo scale.

Measuring photo distance and computing scale.--Having determined a ground distance between two points, you now need to measure between the same points on the photo and compute photo scale. Since the method of figuring scale depends on how you measure the photo distance, the two steps are treated together.

The easiest procedure is to use TSA 16, the multiple photo scale. Knowing the ground distance in the same units as the scale, you simply find by trial and error which scale gives the correct reading. This gives you photo scale without having to remember any formulas or risk of arithmetic error.

Example 3.--In stereogram 1, there are two parallel north-south roads that look like they might run along landlines. We know that these photos come from a project that is supposed to have an average scale of 1:12,000. Using the multiple photo scale at 1:12,000, the distance between the two roads reads 17.5 chains. It seems likely that the roads

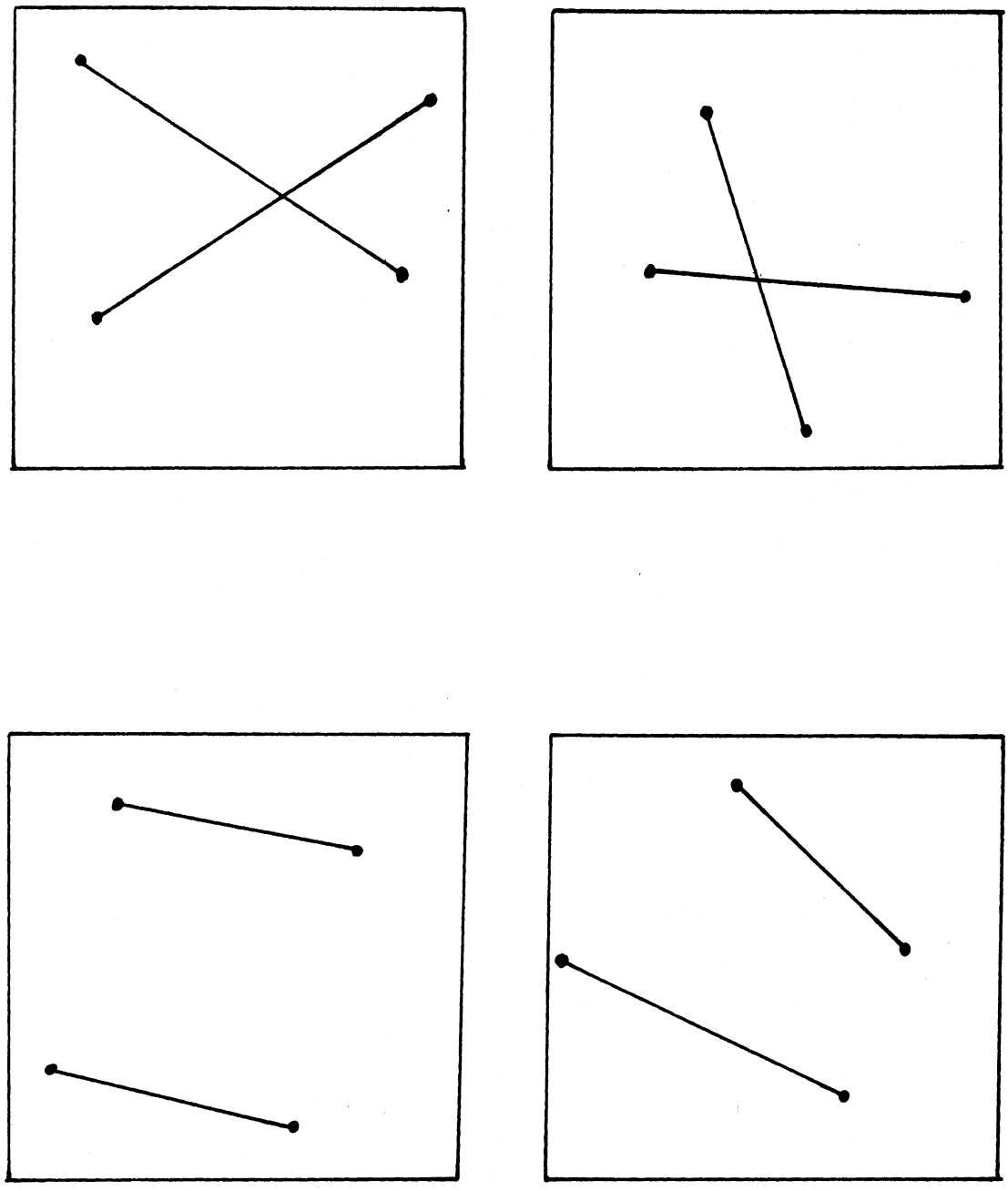


Figure 6.--Examples of pairs of scale check lines fairly well balanced on photo.

are really 20 chains apart and the photo scale smaller than 1:12,000. If we assume the roads are 20 chains apart, we can use the multiple scale to determine the scale of the photos. If, by trial and error, we determine which of the scales gives a reading of 20 chains between the roads, we find it lies between 1:13,000 and 1:14,000, but closer to the latter. Our estimate of photo scale would be 1:13,700 or 1:13,800.

Example 4.--In stereogram 1, you have chained from the road junction at (4) south to the next road junction. The distance is 12.5 chains and the map shows the average elevation of the line to be about 980 feet. Try the multiple photo scale to see which scale gives the correct distance. The reading on the 1:13,000 scale is 12.0 chains, while that on the 1:14,000 scale is 13.0 chains. Your estimate of the photo scale would therefore be about 1:13,500 at an elevation of 980 feet.

If you have only a standard PI scale, you can use it to determine photo scale with the following formula:

$$PSR = (PAR)\,\frac{GD}{PAD}\text{, where:} \qquad (3)$$

PAR = Photo aid reciprocal.

PAD = Photo aid distance.

Example 5.--Suppose that in the last example we had only a standard 1:12,000 PI scale. It reads 11.0 chains for the distance between road junctions which we know from ground measurement should be 12.5 chains. Thus, (PAR) = 12,000 and (PAD) = 11.0. Using formula 3,

$$PSR = (PAR)\,\frac{GD}{PAD} = 12{,}000\,\frac{12.5}{11.0} = 13{,}600$$

Photo distance can also be measured with any sort of engineer's scale or ruler in the decimal system. One reading in hundredths or thousandths of a foot is particularly useful. If you have determined the ground distance by chaining between the checkpoints, simply make sure this is in the same units as your scale and calculate photo scale with formula 2. If you are getting ground distance from a map, it is easiest to use the same measuring scale on both map and photo. Photo scale is then determined from the following formula:

$$PSR = \frac{(MD)\ (MSR)}{PD}\text{, where} \qquad (4)$$

MD = Map distance

MSR = Map scale reciprocal

Example 6.--Using an engineer's scale in 50ths or 100ths of an inch, the map distance (MD) between road junctions in stereogram 1 is about 0.41 inches. Distance between the same two points on the photo (PD) is 0.74 inches. Map scale reciprocal (MSR) = 24,000, using formula 4,

$$PSR = \frac{(MD)\ (MSR)}{(PD)} = \frac{(.41)(24,000)}{.74} = 13,297$$

at 980 feet elevation.

Using more than one scale checkline.--If you use two or more scale checklines, and if ground elevations do not vary more than about 500 feet, you can simply average the photo scale estimates from the several checklines. However, in rough country each scale determination is likely to apply to a different elevation, so a better approach is to convert each to an estimate of flying height above sea level, and average these. You can then determine photo scale for any particular elevation from formula 1.

To get flying height from photo scale, we can rearrange formula 1 thus:

$$H = (f)(PSR) + h \qquad (5)$$

Example 7.--Suppose that on a stereopair of rough country we pick two scale checklines. Using a map, an engineer's scale, and formula 4, we get from the first checkline:

$$PSR = \frac{(MD)(MSR)}{(PD)} = \frac{(1.01)(62,500)}{4.93} = 12,805$$

$$\text{at } \frac{1,550 + 1,520}{2} = 1,535 \text{ feet elevation}$$

and, from the second: $PSR = \frac{(1.29)\ (62,500)}{6.70} = 12,035$

$$\text{at } \frac{2,300 + 2,350}{2} = 2,324 \text{ feet elevation}$$

The two scale estimates differ by 6.4 percent, but this is largely due to the elevation difference of our scale checklines. Using formula 5 to convert each checkline to an estimate of flying height,

From the first, H = (1)(12,805) + 1,535 = 14,340 feet

From the second, H = (1)(12,035) + 2,325 = 14,360 feet

Average H = 14,350 feet

Our two estimates of flying height differ by only 0.1 percent, so we can average them and then use formula 1 to get photo scale for any particular ground elevation.

Adjusting for elevation difference.--It often happens that the place where you want to make a photo measurement is considerably higher or lower than the checkline you used to get photo scale. For example, you may have chained along a road in the valley, but you want to measure the distance from reference point to plot center, both of which are 800 feet higher on a ridgetop. If you have a topographic map, or can estimate this height, it is relatively easy to adjust photo scale from the elevation for which it is known to that for which it is desired by making use of the relationship in formula 1.

For each foot of elevation change, the PSR changes by 1.0 if the lens is 12 inches, by 1.4545 if the lens is 8 1/4 inches, and by 2.0 if the lens is 6 inches. For any other focal length the change is 1/f. If the new elevation is higher than the old (closer to the aircraft), then the scale change is subtracted, giving a smaller PSR. If the new elevation is lower than the old, the scale change is added, giving a larger PSR.

The following tabulation shows the relation between elevation change and scale change for the three common lenses.

Scale Change Associated with Elevation Change

Elevation change ($h_1 - h_2$)	12-inch (1.0 feet)	8 1/4-inch (.6875 feet)	6-inch (0.5 feet)
(Feet)	(Change in PSR--sign opposite elevation change)		
1±	1	1.4545	2
200±	200	291	400
400±	400	582	800
600±	600	873	1,200
800±	800	1,164	1,600
1,000±	1,000	1,455	2,000
1,200±	1,200	1,745	2,400
1,400±	1,400	2,036	2,800

Example 8.--Suppose you have estimated the scale of a photo taken with an 8¼-inch lens as about 1:16,000 from a checkline at an elevation of 1,560 feet. Now you want to measure the distance from a reference point to a plot center along a line which averages about 2,000 feet in elevation. This is about 440 feet above the elevation of the checkline. For an 8¼-inch lens, the PSR changes by 1.4545 for each foot of the elevation change, and, since the new elevation is higher than the old, the scale change is subtracted. Hence the PSR at the elevation of the plot is 16,000-(440 X 1.4545)= 16,000-640 = 15,360.

Whether or not to bother adjusting scale this way depends on the amount of the elevation difference, the flying height, the precision you want, and the length of the line you want to measure. For instance, in the foregoing example, failure to adjust photo scale for the elevation change would have resulted in a measurement error of about four percent, not enough to bother us on a short distance of less than 10 chains. However, with greater elevation differences or longer distances, the error would become more serious.

Photo project scale.--If measurements are to be made on many photos in a project, it becomes laborious to make a scale check on each one. If the country is not too rough, you may find by checking a dozen or so photos that an average scale for the whole project is good enough. If there is too much variation to suit you, try checking the flying height at several points along a flight line. Often it is constant for alline, though it may vary between lines. However, in 1:12,000 photo projects of rough country, flight altitude is often changed several times in a single flight line; in this case, you will have to check the scale of every photo you want to measure on.

Measuring Distances on Photos

Once photo scale is known at the proper elevation, horizontal distance can be measured on the photo with any kind of a scale. The easiest to use is one of the multiple photo scales, for it reads directly without requiring any calculation.

Example 9.--Suppose that in stereogram 3 you wish to measure the distance from the sharp bend in the logging road to the center of plot 15. You have previously determined the photo scale to be 1:15,400 at approximately this elevation. Using the multiple photo scale between the 1:15,000 and 1:16,000 scale lines, the distance from plot center to near edge of the road measures about 11.5 chains.

If you do not have a multiple photo scale, you can use an engineer's scale in 1,000ths of a foot or inches. Ground distance is obtained by the following rearrangement of formula 2.

$$GD = (PD)(PSR) \qquad (6)$$

Example 10.--Repeating the same problem as example 9, we measure the distance from road to plot 15 with an engineer's scale, getting 0.60 inches. Since there are 792 inches in a chain, we will have to divide the ground distance by this to get chains.

$$GD = (PD)(PSR) = \frac{(.60)(15,400)}{792} = 11.7 \text{ chains}$$

If you have only a standard photo aid for a single scale, you can use it with this rearrangement of formula 3.

$$GD = (PAD)\frac{PSR}{PAR} \qquad (7)$$

This will work even if you happen to be caught with a photo aid for the wrong scale, or with only the scale on the map legend.

Example 11.--Again, on the same problem as examples 9 and 10, you measure the distance with a photo aid for 1:12,000 photos as 9 chains.

$$GD = (PAD)\frac{PSR}{PAR} = (9)\frac{15,400}{12,000} = 11.6 \text{ chains}$$

Measuring Angle or Direction

Frequently you will want to find your way to a field plot or suspected section corner location which has been spotted on an aerial photo. If you cannot find it by following the photo detail, the best way is to run a line in from a reference point you can identify. The direction of this line, as well as its distance, can be measured on the photo.

To get the direction of this line, you need only find on the photo some other line whose azimuth or bearing is known, or can be determined. The direction of the wanted line can then be found by measuring the angle between it and the known base line. There are three ways of getting the base line.

Since most aerial photos are taken in cardinal directions, you could assume that the photo edges are cardinal. You cannot get very far off if you are running a line only a few chains long. However, since photo crab of 5^{o} or 10^{o} is not uncommon, you would not want to run a long line on this assumption.

If rectangular landlines show on the photo, they can be used as base lines. Some sections are not run in cardinal directions, so it helps to have a map of the area.

Example 12.--In stereogram 1, suppose you wish to know the azimuth of a line from the road junction in the lower left corner to the center of the nearby letter "A." Draw a line between the two, extending it at least one inch beyond A. You judge by looking at the photo, and this can be confirmed by reference to the map, that some of the roads run in cardinal directions. Place your protractor on the photo, with the center at the road junction and the N and E lines oriented on the

roads. The protractor is now correctly oriented to true north and the azimuth of any line passing through the road junction can be read. The line through the center of A reads about 40^{o} or 41^{o}.

If no landlines show on the photo, a base line can be established by a compass shot in the field, using a fence line, straight piece of road, or any two objects you can sight between and spot on the photo.

Example 13.--In stereogram 3, you want the direction of a line from the top of the bluff at 7 (where the tip of the arrow touches it) to the center of plot 14. Standing at this point on the top of the bluff you can see the landing in clearcut area 5, and a compass shot reads 75^{o}. Draw this line on the photo--it is your base line of known azimuth. Now draw the line from the arrow point at the top of the bluff to the center of plot 14 and on beyond for another inch. Orient your protractor with the center at the intersection of these two lines and rotate it until the line to the landing reads 75^{o}. The azimuth of the line to plot 14 reads 190^{o}.

The third way to get a base line of known direction is to draw lines between pairs of identical points on both map and photo, measuring the azimuth of the line on the map.

Example 14.--On the photo EGI-50-153, you wish to run a compass line from the road junction at C to the center of the letter "A." There is no straight stretch of road nearby along which to take a compass shot for a base line, so you decide to get a base line azimuth from the map. On both the photo and the map, draw a line between road junctions C and N. Place your protractor on the map with the center where this line crosses the N-S township line, and oriented on this township line. The azimuth of the line C-N reads 78^{o}. Now on the photo draw the line from the road junction at C to the center of the letter "A." Orient the protractor over the intersection of the two lines, rotate it until the line to N reads 78^{o}, and read the azimuth of the line to A as 41^{o}.

Measuring Areas

Two types of area estimates are generally used by the forester. He sometimes needs to know the total acreage of the various condition classes making up a gross area such as a working circle. However, he often wants to estimate the acreage of a specific area, like a type island or timber sale area. Since many of the area classes desired are visible from the air, aerial photos are highly useful tools for collecting area data.

Area estimates by condition class can be obtained in two ways. If the gross survey area has not been stratified into condition classes (type islands) by a type map, these estimates can be obtained by sampling points on the photos. However, if a type map has been made, areas can be measured directly, either on the mapped photos or on the base map to which the types have been transferred. The following paragraphs describe some of the more widely used techniques for measuring areas.

Planimeter

The planimeter is an old standby for measuring areas. To measure the area enclosed by a boundary, a tracing point on the instrument is run around the perimeter. Readings on the instrument dials are then converted to areas. This method is especially adapted to measuring small areas. Since the entire area is measured, there is no sampling error associated with the area estimates. There will be a certain amount of technique error, but this is small if care is used.

Dot Grid

The most widely used method of estimating areas is the use of dot grids. Dot counting involves a minimum of special equipment, and is well suited to the estimation of area totals from a type map. Dot grids are also used in estimating the acreage of individual areas on photos. Dot counting is usually done by superimposing a transparent dot grid over the map or photo mosaic of a survey unit and tallying each dot according to the individual type island it falls in.

When working with type maps, the number of acres represented by each dot can be found from the intensity of the dot grid and the map scale. Dot grids usually have a certain number of dots per square inch. And type maps are usually printed at a scale that makes it easy to figure the number of acres per square inch. At a scale of one inch to a mile, it is 640 acres; two inches to a mile, 160 acres; or four inches to a mile, 40 acres. Dividing the acres per square inch by the dots per square inch gives acres per dot. Thus, with a four-inch to the mile map, and a grid with 64 dots per square inch, the acres per dot equals 40/64 = .625.

Example 15.--You wish to obtain the acreage of cutting unit No. 5 on the Keechelus Lake Area map. The scale of the map is 1:15,840. The acres per dot using a 64 dot per inch grid is .625. We counted 66 dots in the area, 66 x .625 = 41.2 acres. The planimetered acreage was 42.4 acres.

If the type map is at an odd scale or when working with aerial photos, you can figure the acres per dot from the following formula.

$$A/D = \frac{(MSR)^2}{(6,272,640)(GI)}, \text{ where:} \qquad (8)$$

GI = Grid intensity (dots per square inch).

Example 16.--With an aerial photo type map scale of 1:12,500 and a grid with 64 dots per square inch, how many acres are represented by each dot?

$$A/D = \frac{(MSR)^2}{(6,272,640)(GI)} = \frac{(12,500)^2}{(6,272,640)(64)} = .389$$

For the widely used grid of 64 dots per square inch, this formula reduces to:

$$A/D = \frac{\left(\frac{MSR}{10,000}\right)^2}{4} = \frac{(1.25)^2}{4} = .390 \qquad (9)$$

Example 17.--On EGI-50-153 you wish to estimate the total acreage of the two clearcut areas just SW of E. You have a dot grid with 64 dots per square inch. The photo scale had been calculated to be 1:14,000. Using formula 9, acreage per dot equals $\frac{(1.4^2)}{4} = .49$

Since there is some subjectivity in determining the exact boundary of the clearcuts, estimates of acreage can vary. We counted a number of times and got counts ranging from 29 to 32 with an average of 31.2. This gives 15.3 acres.

When working with aerial photos of fairly level terrain, an average scale for the whole photo area can be calculated and applied. However, in areas with considerable differences in elevation, photo scale can vary quite a bit between type islands. Using an average scale would introduce some error in your area estimates. If calculating the photo scale at each individual type island is too much of a chore, you can transfer the entire type map from the photos to a base map with a radial line plotter, and then measure them. If there are only a few areas to measure, such as recent clearcuts or a proposed timber sale area, they can either be measured on a base map following transfer by a radial line plotter or directly on the photo using the photo scale of the immediate vicinity. When measuring directly on photos, choose the photo on which the area being measured is closest to the center. Probably the best method for measuring the area of a specific type island is the planimeter. However, if one is not available, you can use a dot grid. First, determine the number of acres represented by each dot at the scale of the map or photo, then multiply by the number of dots falling in the type island.

If you are working with a photo mosaic of a survey unit, such as a compartment, and the gross area is known, an estimate of type island acreages can be easily made. The number of acres per dot is calculated by dividing the acreage by the total number of dots counted. The acreage-dot ratio is applied to the number of dots falling in type island. The acreages calculated, while not as accurate as those developed by the preceding methods, are probably useful for broad planning purposes.

When a great deal of dot counting is necessary, an electric dot counter is useful. This device consists of a plastic sheet with a series of drafted parallel lines, and at right angles to these, another series of metallic lines which conduct electric current. This grid is placed over the map, and an electric pencil is run along the drafted lines. Each time the pencil crosses a metallic line, an electric counter tallies another dot.

Transect

Another method for sampling to get area estimates is the line transect. A series of lines are drawn on a transparent overlay and the overlay is placed on the map or photo. These lines are usually spaced at even intervals. The total length of all lines passing through each type island is measured. This total line length is converted into acreage by an acreage-inches of line ratio. This ratio is derived from the scale of the photo or map and the interval between lines. A watch-type map measurer, obtainable at most stores stocking engineering supplies, is the recommended instrument for measuring lines.

CHAPTER 4

PHOTO INTERPRETATION

Aerial photographs contain a wealth of detailed information not normally shown on maps. This can be invaluable to you as a forester if you can identify the objects shown and correctly judge their significance, the process of photo interpretation.

To a considerable extent photo interpretation is a subjective process, perhaps more of an art than a science. The interpreter often makes measurements and uses various aids, such as keys and stereograms, for visual comparisons. Moreover, effort is currently being aimed at developing techniques for automating the job. But, for the time being anyhow, success depends primarily on the human interpreter, his judgement and skill developed through experience.

In this chapter we will present some pointers to help you in identifying the objects pictured on aerial photos. All we can do is illustrate some principles we have learned and found useful. You can develop the necessary skill only by accumulating experience, mainly by visiting the field with photos in hand, comparing the appearance of objects on the photos and on the ground.

Principles of Photo Interpretation

When we look at an aerial photo, we quickly recognize many familiar objects without being conscious of what tips us off. We are actually making use of certain photo image characteristics: tone, size, shape, shadow, texture, pattern, and location or relation to surrounding objects. Knowing what these characteristics are and how they work should help you improve your interpretation ability more rapidly.

Many objects photograph with a characteristic tone or range of tones. Since tone is affected not only by the object itself, but also by many other factors in the taking and processing of the photos, it is not consistent enough to be used for precise identification. Nevertheless, your judgment of relative tone differences, plus some understanding of the reasons for them, will help you identify many photographic images. As an example, in Stereogram 3, note the marked tone difference between the stand labeled (H2≡d) and that labeled (FM3≡a). This is caused by a species difference--the western hemlock in the first stand characteristically photographs a light tone, while the Pacific silver fir in the second stand is invariably dark.

Image size and shape are obviously important clues to object identity, and shadows sometimes help define a shape which is otherwise obscure. Size, of course, can be measured, both in the horizontal and vertical directions, but your judgement of relative size is often sufficient for identification.

In Stereogram 3, images 1, 2, and 3 all have the distinctive shape of manmade transportation routes. By checking size, you can determine that 3 is an improved road suitable for log hauling, 2 is a narrow unimproved road, while 1 must be a trail or possibly a jeep track.

Texture refers to the impression you get of the surface of an area, usually composed of many small images. There is no standardization of terminology, and texture names include simple terms like coarse and fine as well as more descriptive ones like pebbly and feathery. Many types of vegetation and ground surface have characteristic textures. For example, in Stereogram 8, the texture in the vicinity of H could be called woolly.

Pattern is the arrangement of similar images, and may be either regular or irregular. It is often a very useful clue for identifying objects and reducing their significance, or for determining past or present land use. For example, in Stereogram 3, pattern is the chief clue to the land-use history of areas 4 and 5. The skid trails in area 4 show the typical dendritic pattern of tractor logging, while the radiating skid trails in area 5 furnish conclusive evidence that this setting was logged by cable.

Studying the location of an image in relation to its surroundings often helps identify the object, or at least narrow the field of possibilities. Image Number 6 in Stereogram 3 has the size, shape, and tone of a road. However, its location around the edge of a clearcut tips us off to the fact that it is a fireline.

Identifying Forest Types

When you attempt to identify forest types you will use the principles just described, studying the tone, size, shape, shadow, texture, and pattern of the images in relation to their surroundings. Field experience in the particular area with photos in hand will be especially valuable to you. This is the best way to learn the appearance variations to be expected and the reasons for them. Moreover, you will discover what types to expect in certain situations and which ones to eliminate from consideration.

The following discussion covers some of the forest types found in the Region. These are illustrated in some of the figures and in the stereograms that accompany this manual. The type scheme legend that follows is used by the Forest Service. We have included only those types that are illustrated.

This material covers forest types only. Instructions for classifying lands into other condition classes such as nonforest land and noncommercial forest land are found in other texts.

Forest Types

Forest type designations consist of one or two letters, indicating species type; a number, representing stand-size class; and one to three bars, indicating stocking class. Lowercase letters following the stocking class indicate secondary species comprising 20 percent or more of the basal area or volume. Types with a numerator and denominator are dual types having an overstory and understory.

Species Type

D	Douglas-fir
P	Ponderosa pine
H	Western hemlock
FM	True fir-mountain hemlock

Stand-Size Class

1	Seedling and sapling (less than 5 inches d.b.h.)
2	Poletimber (5 to 11 inches d.b.h.)
3	Small sawtimber (11 to 21 inches d.b.h.)
4	Large sawtimber (21 inches and larger d.b.h.)
5	Old-growth large sawtimber (21 inches and larger d.b.h.) (used for Douglas-fir types only)

Stocking Class

_	Poorly stocked (10 percent to 39 percent)
=	Medium stocked (40 percent to 69 percent)
≡	Well stocked (70 percent or more)

Individual Species Components

D	Douglas-fir (*Pseudotsuga menziesii*)
h	Western hemlock (*Tsuga mertensiana*)
p	Ponderosa pine (*Pinus ponderosa*)
nf	Noble fir (*Abies procera*)
a	Pacific silver fir (*Abies amabilis*)
wf	White fir (*Abies concolor* or *Abies grandis*)

Species Type

The degree of success in identifying the Northwest's species types varies with the particular area, the photography used, and the interpreter's experience. Some types are quite distinctive and can usually be recognized wherever they occur. Others can be spotted part of the time, while some types are almost impossible to identify.

Both individual tree characteristics and overall stand appearance are useful in identifying species types. Sometimes you can determine the type because you recognize the individual trees that constitute a majority. At other times you classify a type because of its general appearance and location, even though you cannot recognize individual tree species.

Species types often change appearance somewhat from one area to another or between photo projects. Therefore, rather than try to present a complete guide to type identification, we will point out some of the tree and stand characteristics to look for. We believe they will help you in learning to get the most type information from your photos in your own area.

Our comments are based on the assumption that you will be using panchromatic photos, since the bulk of the photography in this region is that type. With infrared you could do a quicker job of separating hardwoods from softwoods, but that is about as far as its advantage seems to go. Color film suggests intriguing possibilities, but it is not in general use as yet.

The characteristics most useful in identifying individual tree species or stands are: site or location, tone, texture, pattern, tree size, crown shape, and branching pattern. Examples of how these apply are shown in Stereograms 3 and 5, and the EGI photo pair. As you read the following comments, study these stereograms and verify our generalizations.

A knowledge of where the various types are, or are not, likely to occur is important, since it enables you to narrow the field of possible choices. Knowing the geographic range of the various species is a starting point, and it can be further refined by learning their site preferences.

Photographic tone alone is seldom conclusive evidence of tree species but is a big help when combined with other evidence. Sometimes, on small-scale photos, tone is about all we have to go on. Since the shadow side of most tree crowns is quite black, tone should be judged on the sunny side. If we adopt the medium-toned Douglas-fir as a standard, hemlock and ponderosa pine are usually somewhat lighter, western red cedar is much lighter, while Pacific silver fir is invariably darker. The dark tones of silver fir is so distinctive, it can usually be spotted easily on photos as small as 1:50,000.

Some tree crowns have distinctive textures. Douglas-fir and ponderosa pine are about medium; most true firs are quite smooth; Sitka spruce and black cottonwood are rough; hardwoods are usually woolly. Also, some species have a characteristic texture when in pure stands. Note, for example, the feathery texture of the H4 stand in Stereogram 5.

The relative size of trees is of limited usefulness in identifying tree species because of variations in age and site. However, it should not be ignored, for some trees tend to have a characteristic size in relation to associated species. For instance, lodgepole pine is always small; Sitka spruce tends to occur as dominants; and Pacific silver fir is often an understory.

Pattern applies to stands rather than individual trees. Lodgepole pine stands have a rather characteristic pattern created by the close and even spacing of small crowns. Pattern is also one of the best clues to the Douglas-fir stands on the EGI photo pair. Douglas-fir stands typically have a regular pattern of closely spaced even-sized crowns, while ponderosa pine stands usually have an irregular pattern of widely spaced uneven-sized crowns.

On 1:12,000 scale photos you may be able to see enough of the crown shape and branching pattern to identify individual trees if they are mature. Unfortunately, these characteristics seldom show up in immature trees.

An idea of crown profile can be obtained from the vertical stereo view, from the semiprofile at the photo edge, and occasionally from shadows. Many species have distinctive crown profiles. Incense-cedar appears conical; Pacific silver fir, bullet-shaped; noble fir, rounded; Engelmann spruce and subalpine fir, spire-like; ponderosa pine, ball-shaped; western hemlock, pagoda-shaped; and white fir, columnar.

Branching patterns are also distinctive on some species. Note on the stereograms that western hemlock has fine radiating branches like a wagon wheel, the branch sprays of noble fir give it a rosebud appearance, while sugar pine typically has a few long branches that make it look like a starfish. Pacific silver fir and ponderosa pine branches seldom show. Douglas-fir is often this way too, though at times the branches show prominently like western hemlock.

CHAPTER 5

FIELD USE OF AERIAL PHOTOGRAPHY

Probably the most widespread use of photos by foresters is for simple field guidance in the conduct of many daily tasks. Nearly every forester with normal eyesight can get some helpful information from the photos which will make his field chores easier.

In most of these cases, the photo is used as a map substitute because it furnishes far more detail than a map could possibly provide. Not all the information desired by the forester can be seen on the photo. However, much of it can and the forester is often able to see at a glance what it would take him hours of field travel to determine. Office study of the photos prior to the field visit enables him to plan his trip more efficiently. And use of the photos in the field saves the forester time and lost motion by showing him what's over the hill and enabling him to spot areas he does or does not have to check.

This chapter is a practical guide to help foresters use photos in the woods. It is assembled from the experience of a number of men with many years of forest inventory and photo-interpretation practice behind them. The suggestions presented here apply to such field uses as: inventory plot location, section corner location, road reconnaissance, timber sales preparation, and general woods travel.

Field Viewing and Marking Techniques

The basic equipment for field use of aerial photos consists of a stereoscope, a holder to protect the photos while traveling, some sort of scale and protractor, a needle point, and a pencil for marking on the photo surface.

The most common stereoscope in field use is the folding pocket type, which is a simple instrument, well adapted for both field and office use. It can stand quite a bit of rough use in the field, but does have a weak point in the thin metal bar that connects the two eyepieces. This can be broken by a sudden jar. For this reason, it is wise to fold the stereoscope and put it in its case when not using it. Some foresters prefer the type of stereoscope mounted by a moveable arm on a clipboard or other rigid surface. While not as handy to carry as the pocket stereoscope its lack of legs gives more freedom for moving the photos or marking on them.

The ordinary letter-size aluminum tatum makes a satisfactory holder for carrying the photos. It also serves as a table for stereo viewing when it is laid across the lap while sitting on a log or crouching on the ground. A suitable waterproof cover for photos can be constructed

from .015-inch clear plastic, bound on three edges by plastic tape. The photographs can be viewed in the covers if it is raining, and the holders, though somewhat limber, are better than nothing for a table. Various special clipboards and viewing devices made from hardboard or cardboard appear in the literature from time to time.

The handiest type of scale to carry is one of the various photo aids on film or plastic. These can be obtained in fit the scale, or range of scales, with which you are working. Several also contain a protractor, eliminating the need for carrying one separately.

Precise locations of reference points, plot centers, bench marks, section corners, etc., are made by pricking a fine hole in the photo. Avoid making a large hole, for this obscures the plot center and the surrounding half-acre. To keep the hole fine, use a fine needle and back the photo with a hard surface, such as the tatum, so that only the point goes through the photo. Needles can be mounted in the top of wooden lead pencils and protected when not in use by an eraser or pencil point protector. Or they can be soldered into the carriers of mechanical pencils or ball point pens so that they will retract when not in use.

Some sort of pencil which will mark on the face of the photo is handy for making notes and drawing type lines and symbols which cannot be pricked. Numerous types of pencils and even pens are available, and each has its devotees. The types most commonly used are the grease or china-marking pencils, especially those with fine leads, and soft colored lead pencils.

Using the Photos as a Map Substitute

This part deals with the techniques of using aerial photographs as map substitutes--how to find your way around in the woods, plan travel routes, identify where you are and get to somewhere else.

Route Planning

When a field trip is contemplated, a little preplanning on photos and maps invariably pays off. A few moments' study in the office will give you a mental picture of the country and a pretty good idea of the best travel routes, including alternates. Then when you unexpectedly run across a locked gate or other obstacle, you will not have to spend valuable field time spreading out all the photos and maps looking for another way.

Both maps and photos furnish valuable information on the best roads into the area. In some areas, many miles of road are built every year so it is usually worth the effort ahead of time to canvass all possible sources for the latest maps or photos. Hardly anything is more discouraging than beating your way cross country for several miles, then discovering a new road not shown on your maps or photos.

Generally, the quality and condition of a road can be determined more accurately on photos than on maps. Clues to quality are width, grade, surface, radius of curves, amount of cut or fill, and size of bridges. A careful examination of details may reveal impassable conditions caused by down trees, washouts or missing bridges.

If the area to be visited in the field is off the road, an even greater advantage of photos for route planning becomes apparent. The photos reveal not only the topography, but also the cover conditions and other clues to the ease or difficulty of travel conditions. Interpretation experience in the region is helpful, enabling the forester to translate what he sees on the photos into a picture of travel conditions on the ground.

The best route cross country is seldom a straight line. Generally a quicker, safer, and easier route can be chosen by studying the topography, the cover conditions and the availability of check points along the way. Photos generally reveal more topographic detail than maps. Minor changes in slopes, the depth of gulches, the presence of slides, all help in determining the easiest way from one place to another.

The cover conditions shown by the photos are important considerations in route planning, especially if the forester has experience in the area. The experienced forester will usually choose a longer route through dense timber where he knows the brush will be sparse, rather than go straight across an old burn which the photos show as a tangle of brush and small trees. In some parts of the region the best traveling is along ridge tops, while in other areas the best way to penetrate the brush is to walk right up the rocky stream beds. Certain travel obstacles, such as bogs or cliffs and rock outcrops, can often be detected on photos, and thereby avoided.

In choosing cross-country routes there is another factor to consider. This is the presence of easily identified check points along the way. If the end of the route is marked by a very prominent feature, it may be possible to go directly to it without knowing precisely where you are along the way. However, it is generally necessary to work your way along from one landmark to the next, keeping tract of your location at all times. For this purpose it is desirable to select a route which has scattered along it frequent check points which can be easily identified, both on the photos and on the ground. Examples of these are: creeks, ridges, openings, vegetation type lines, and rock outcrops. If it is necessary to travel a considerable distance without intermediate check points, it may be wise to run a rough compass and pace line so you know where to start looking for the identifiable point.

Keeping Located When Traveling

The art of knowing just where you are at all times when traveling is best learned by practice and by getting lost a few times. However, there are several pointers which should help you learn a little faster.

The best way to keep from getting lost is to plan the route ahead, pick the next check point, and confirm its identification before moving one. If you have a mental picture of what is ahead, you can generally work your way to the next check point without referring to the photos unless you spot something unexpected. This is much easier than blundering ahead in the general direction until you see some kind of landmark you think you can identify, then getting out the photos and trying to locate it.

If you miss a check point, and a reasonable search fails to turn it up, you are probably better off to go back to the last one and start again. If you are just learning this technique, you will probably ignore this advice and stumple on, hoping to find a landmark you can identify. You may be lucky a time or two. But the chances are that, after you have wasted time on several occasions by doing this, you will be more inclined to play it safe rather than to forge ahead even though you are temporarily misplaced.

Exercise caution when identifying check points--do not jump to conclusions. Use the stereoscope, and examine several aspects of the check point to make sure it is the one you want and not one that is just similar. Scan the surrounding area on the photos to see if there is a nearby feature which is similar to the one you are looking for. You might actually be at an opening which just looks something like the one you want. Plan ahead. If you wish to take off up the first creek to the right, know about how far ahead it is. The first creek you come to may be one you did not see on the photos. When you think you have found the correct creek, try to get another feature or two to tie in--timber type, creek bend, snag, gravel bar, etc.

You will find that your ability to identify your location improves rapidly with a little experience. At first the only landmarks you can identify with certainty are the prominent ones--roads, fields, gross topographic features. Soon you will be moving confidently between more subtle check points--small openings, type changes, and minor creek bends. Eventually you will be able to find your way most anywhere by noting details like spike-topped trees, lopsided crowns, species differences, and patterns created by groups of trees. Do not get overconfident, but do not be afraid to believe in your ability once you have proven it to yourself. Our experience in training field assistants indicates that most of the time they are correctly oriented on the photos, and that their confusion is often due to a lack of confidence to proceed ahead.

To make the job easier and more positive, use your stereoscope whenever in doubt, especially in cross-country travel, and orient the photos the way the ground lays. Then when you look up from the stereoscope, everything will be just where you expected it. You will have to get used to the way the topography looks on your particular photos. Photos taken with 8 1/4-inch, and especially 6-inch lenses, give the impression that the country is steeper than it really is. On the other hand, a 12-inch lens flattens things out and what you thought was a moderate slope may prove to be a stiff scramble. The shape of areas on steep slopes near the photo edges will look different than they do on the ground, too.

Do not get careless when following your way along a road, because cultural features stand out so prominently. Sooner or later you will be misled because you picked a road junction, field, or clearcut similar to the one you were looking for. Keep track of mileage and get the feel of how fast you are moving across the photos. Slight bends in the road do not show very well on the photos. To make the road look more like it does to you on the ground, hold the photo horizontally just below eye level and look down the road image at an oblique angle.

Using Photos in Field Plot Work

Aerial photos are commonly used as a tool for locating and referencing field plots, such as those used in forest inventory. Sometimes the plots are picked on the photos themselves, while in other instances they are first located on maps and then transferred to photos. In either case, the final plot location is usually shown by a fine needle prick on the photo. A field crew is then given the job of locating this point in the field and measuring a plot.

The normal procedure for this job is to pick a reference point as close as possible to the plot; select a route to the reference point; travel to, and verify the identification of, the reference point; prick its location on the photo; determine the direction and distance of the line from the reference point to the plot; run this line; and verify the location of the plot. Following are some pointers on other aspects of field plot location.

Choosing a Reference Point

In choosing a field plot reference point the field crew attempts to meet several objectives. One of these is that the point be easily and positively identified. A skilled interpreter with enough time can follow his way tree by tree nearly everywhere. However, the field supervisor attempting to check the plot, or another crew attempting to remeasure it, may not be so clever. Therefore, it is essential that the reference point be unmistakable and one which can be found by others without too much trouble.

If the field plots are to be remeasured at some future date, then it is desirable to have a reference point which is relatively permanent. A tree is commonly chosen as the actual reference point to be pricked on the photo. The advantages are that it is quite precise and it can be blazed and marked. When a choice is available, the reference tree should be one which can be expected to survive until the next plot measurement. Really permanent features, such as creek junctions, rock outcrops and topographic features are usually too large and vague to be pricked. However, if a reference tree near one of these permanent features is pricked, the plot can probably be relocated, even if the reference tree is gone.

Another desirable characteristic of the reference point is that it should be as close as possible to the plot. The closer it is the more accurate the plot location is likely to be and the less inconvenience caused by the compass dictating where you go across rough country. In many cases it is possible to identify the plot location by inspection, without the necessity for running a compass line. However, if the plot is permanent it is still desirable to establish a nearby reference point to be used in case the plot center is destroyed before the next remeasurement. If the plot cannot be located by inspection, the crew seeks the nearest possible reference point which can be positively identified.

Getting to the Reference Point

Tips for route planning and finding you way to the reference point have already been given. About the only thing that needs to be added here is a plea for consideration of the crew which may sometime remeasure the permanent plots you set out. If you make a poor choice on selecting a route in, and discover an easier way out, make a note on the photos or tally sheet. Other instructions for getting to the plot will also help speed the job of finding it again for checking or remeasuring.

The words of caution previously given regarding positive identification of check points are worth emphasizing again here. It is imperative that the plot reference point pricked on the photo and marked on the ground be the same. Checking several features near the reference point to make sure they all fit in will help confirm the identification. If there is any doubt, be sure to examine on the photos any other features which could possibly be mistaken for the reference point.

From Reference Point to Plot Center

Having arrived at, and double-checked the identification of, the reference point, the crew now needs to know the direction and distance from here to the plot. If satisfactory maps are available, this may already have been done, before the crew left the car. However, most crews prefer to wait until they arrive at the reference point, because sometimes changes since photography ruin the original reference point, or field inspection results in selecting a better one.

The techniques for determining direction and distance are described elsewhere, but a word of caution is in order here. Some maps are satisfactory for determining both direction and distance, and this can be done either in the office or the field. However, if photo scale and base azimuth are to be determined in the field, the time to think about it is before you get to the reference point. Generally, by the time you reach the reference point, it is too late to find a satisfactory place to measure a base line for distance or direction.

Usually the best place for this is on the road or on the route between the road and reference point. So this phase of the job must be a part of the planning. If base line distance and direction are to come from field measurements, the best place to do it should be selected at the time the route is being planned.

The question of how accurate the plot location needs to be depends on the survey design. If the field plot is temporary, probably the only reason for referencing it at all is to enable some of the plots to be check-cruised. In this case it is probably sufficient that the reference point be accurately located and the line to the plot marked so that it can be followed. The field plot center need not fall precisely on the needle prick, and the field crew can put away their photos once the reference point location has been confirmed.

However, other designs make it desirable that the field plot center be precisely where the photo is pricked. This applies in any case where supplementary photo plots are used to improve certain area or volume statistics. This procedure requires that adjustments be developed from the relation between photo and field estimates, and these adjustments become meaningless if the photo and field observations are not made at the same points.

Another incentive for accurate field plot location occurs when plans call for remeasuring the plots at some future date. When this time comes, some of the original reference points probably will have been destroyed. It may be necessary in some of these cases to select new reference points and run new lines to the plots. Naturally, it will be difficult to find the original plot if it was not located in the right place.

If the survey design calls for accurate plot location, the field crew needs to do more than just run a predetermined direction and distance from the reference point. Errors in estimating photo scale and baseline direction can result in plot mislocation, especially if the plot is a considerable distance from the reference point. Often, such mislocation can be detected and corrected by careful photo interpretation.

There are two ways to do this. One is to make frequent checks along the compass line, adjusting the direction, if necessary, to make the field line coincide with that drawn on the photo. The other is to check by frequent interpretation along the line, but not adjust the position of the line. Rather, just keep track of where the line is and, when it comes opposite the plot center, offset a recorded direction and distance to the plot. In some cases, as when the plot falls in an even, dense forest canopy, it may not be possible to check or adjust the plot location. Here you will simply have to depend on an accurate job of determining the proper distance and direction and running of the line.

PROBLEMS

1. In stereogram 1:

   a. Road section 1-2 is: cut fill neither
      Road section 2-3 is: cut fill neither
      Road section 3-4 is: cut fill neither

   b. Which is higher in elevation: 3 or 5

2. In stereogram 5:

   a. The opening at A is: level gently sloping steep

      The aspect is: N. E. S. W. None

   b. The opening at B is: level gently sloping steep

      The aspect is: N. E. S. W. None

   c. The topographic feature at C is: hilltop ridge bench
      side slope draw saddle

   d. The topographic feature at D is: hilltop ridge bench
      side slope draw saddle

3. Using photo EGI-50-153 and the map, pick a good pair of scale checklines for determining photo scale from the map. Use the letters to designate the checkline terminals.

4. Since the country is relatively flat, compute the average photo scale from the checklines you have chosen.

5. On the same photo, the distance between centers of road intersections I & L has been measured as 23.5 chains. On the basis of this, what is the photo scale? What method did you use?

6. (a) Determine photo scale at two or more points on ELC 2-156 using the accompanying topographic map.

   (b) Using the scale, check points and the elevation as determined from the topographic map, determine the flying height above sea level (H). Focal length of camera is 12 inches.

   (c) What is the photo scale at the point where the road enters the cutting unit in the upper right-hand corner of the photo?

7. (a) Determine photo scale at two or more points on ESG 6-26 using the accompanying topographic map.

   (b) Using the scale, check points and the elevation as determined from the topographic map, determine the flying height above sea level (H). Focal length of camera is 8 1/4 inches.

   (c) What is the photo scale at the top of Bishop Mountain? Use the formula PSR = $\frac{H-h}{f}$ and the factor on page 25 of Chapter 3.

8. The scale of photo EGI 50-154 has been calculated to be 1:14,000. What is the distance between point E on the road and the edge of the clearcut at D?

9. A compass shot along the road from M to H reads 216° true azimuth. Again determine the azimuth of a line from E to D.

10. Using the top of the photo as true north, determine the azimuth from road junction L to plot 18.

11. (a) Determine the acreage for cutting units 2-5 as delineated on the planimetric map for Keechelus Lake, using a dot grid. Map scale is 1:15,840.

   (b) Determine the acreage for cutting units 1-5 on Photo ELC 2-156, using a dot grid. Calculate photo scale at each point from information obtained in 6.

12. Identify the following objects:

Stereogram	Object
1	6
3	7
8	C-G-F

13. (a) In stereogram 8, plot 16 has been pricked on the photo as an inventory plot. You have the responsibility of finding that point on the ground and taking the plot. Which of the reference points 1, 2, 3, or 4 would you pick, and why?

   (b) Describe by using the letters on the stereogram how you would find your way from the road at A to the reference point you have chosen.

   (c) Assume you are going to run a rough compass and pace line from point 1 to the opening at points 2 and 3. A compass shot along line C-G-F reads 105° true azimuth. What is the azimuth and distance to the opening?

   (d) What is the azimuth and distance from RP3 to the center of plot 16.